Ambio

Electronic Supplementary Material

This supplementary material has not been peer reviewed.

Title:

Development and Modelling of realistic retrofitted Nature-based Solution Scenarios to reduce Flood Occurrence at the Catchment Scale

Authors:

Valerie Chen, Ricardo Bonilla Brenes, Fernando Chapa and Jochen Hack

1 Supplementary material

Appendix S1. Characteristics of the representative area and placement potential for each UGI.

Road hierarchy	Access road	Local road	Residential road	Residential road small
Road lanes (both)	8,00	5,80	4,00	4,00
Sidewalk (without green verge)	2,50	1,50	1,50	1,00
Green verge	1,00	0,50	0,50	-
Gutter	0,55	0,55	0,55	0,55

Fig. S1: Landscape characteristics that were considered as constraints to a realistic implementation of UGI elements: (Left) street design and dimensions of different hierarchical roads, (middle) spatial distribution of road hierarchy, and (right) existing green network and available open space for UGI in the representative neighbourhood (Fluhrer and Hack 2020).

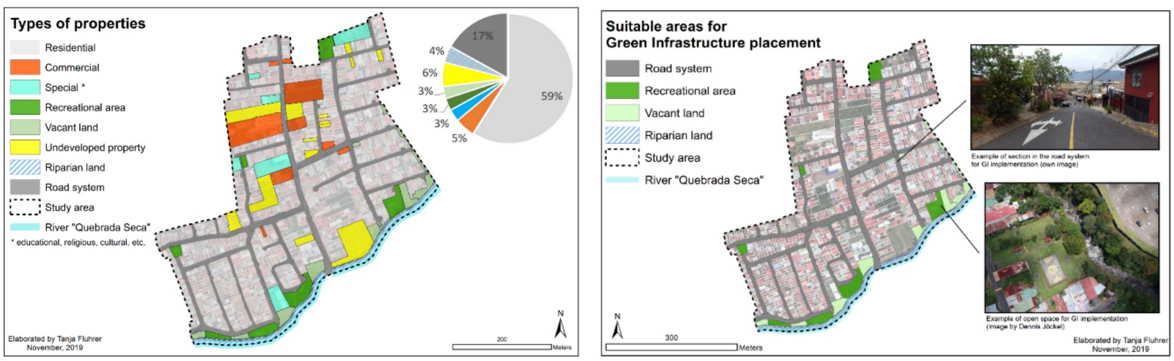

Fig. S2: Land-use and areas considered as suitable for the placement of UGI within the representative neighbourhood (Fluhrer and Hack 2020).

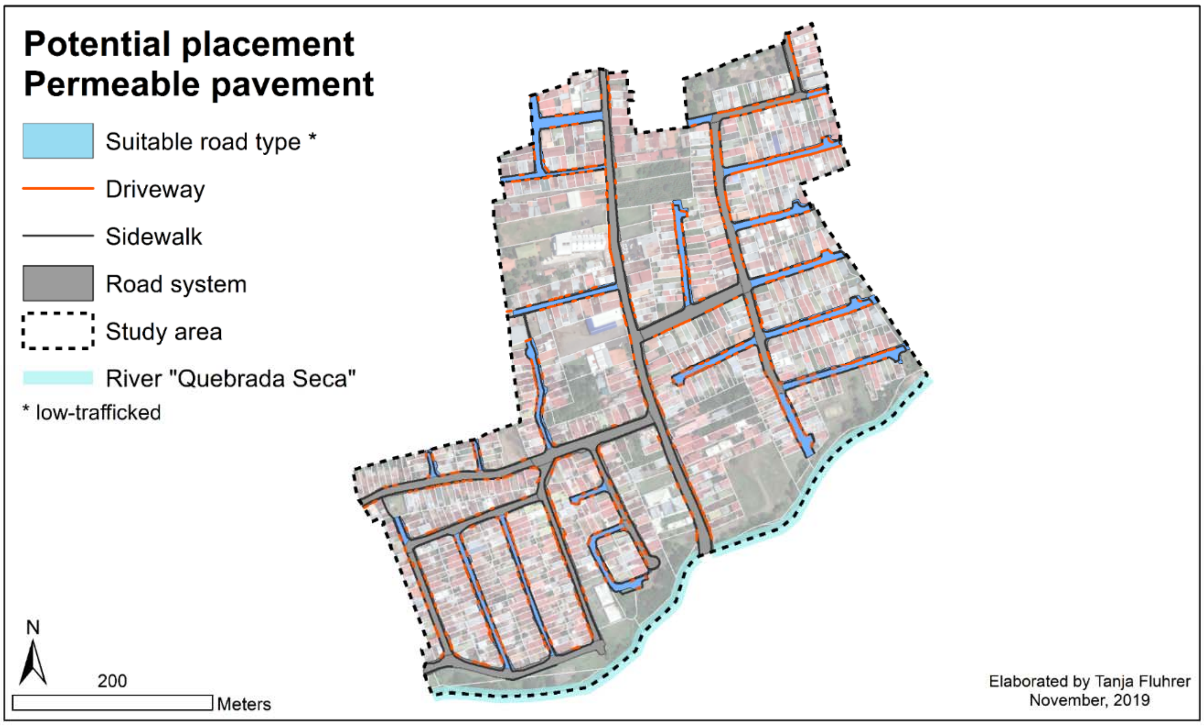

Fig. S3: Potential placements for permeable pavement identified in the representative neighbourhood (Fluhrer and Hack 2020). Source of background image: Google Earth.

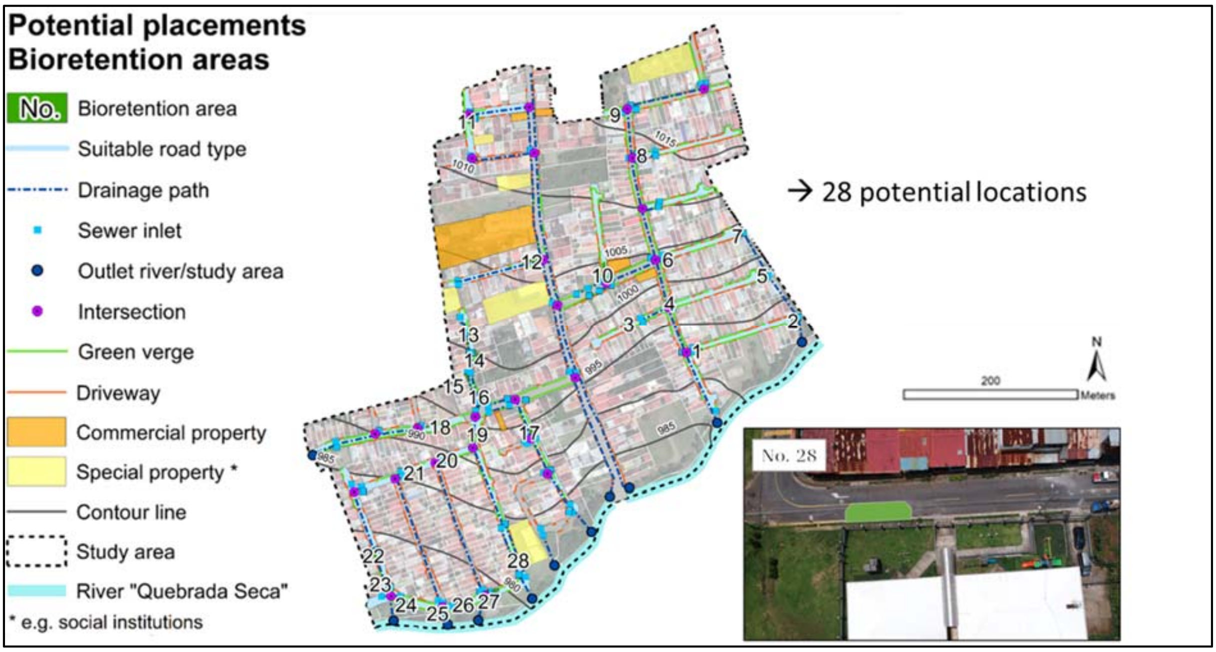

Fig. S4: Potential placements for bio-retention areas identified in the representative neighbourhood (Fluhrer and Hack 2020). Source of background image: Google Earth.

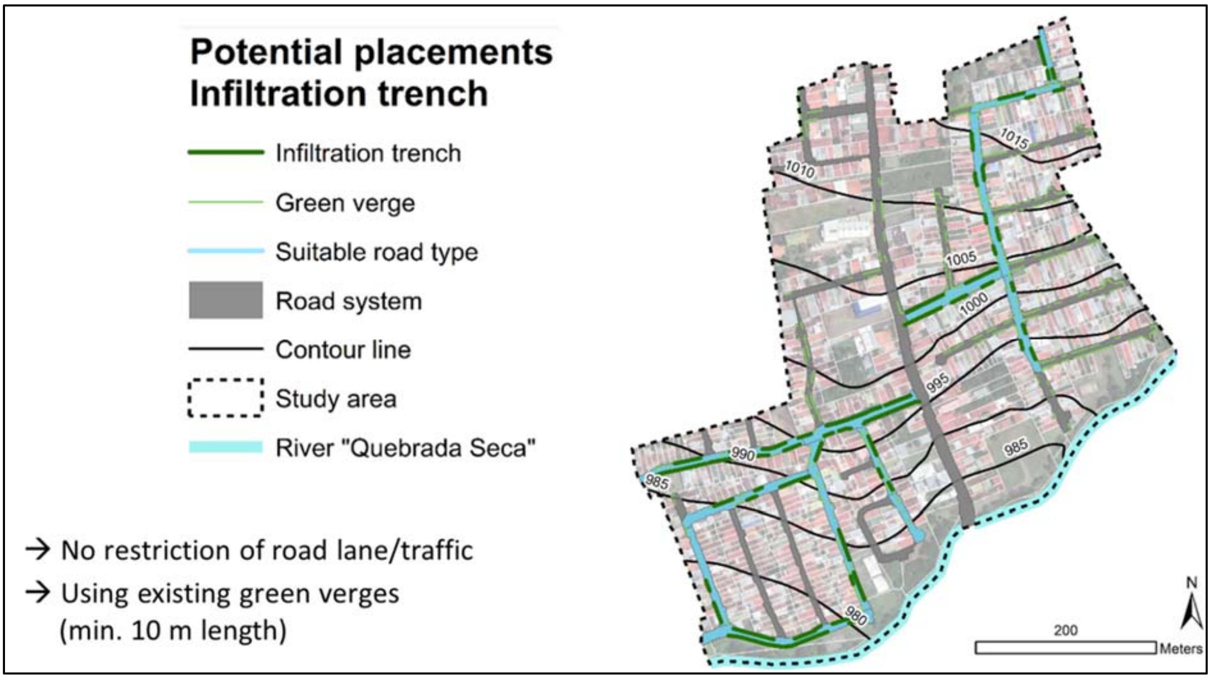

Fig. S5: Potential placements for infiltration trenches identified in the representative neighbourhood (Fluhrer and Hack 2020). Source of background image: Google Earth.

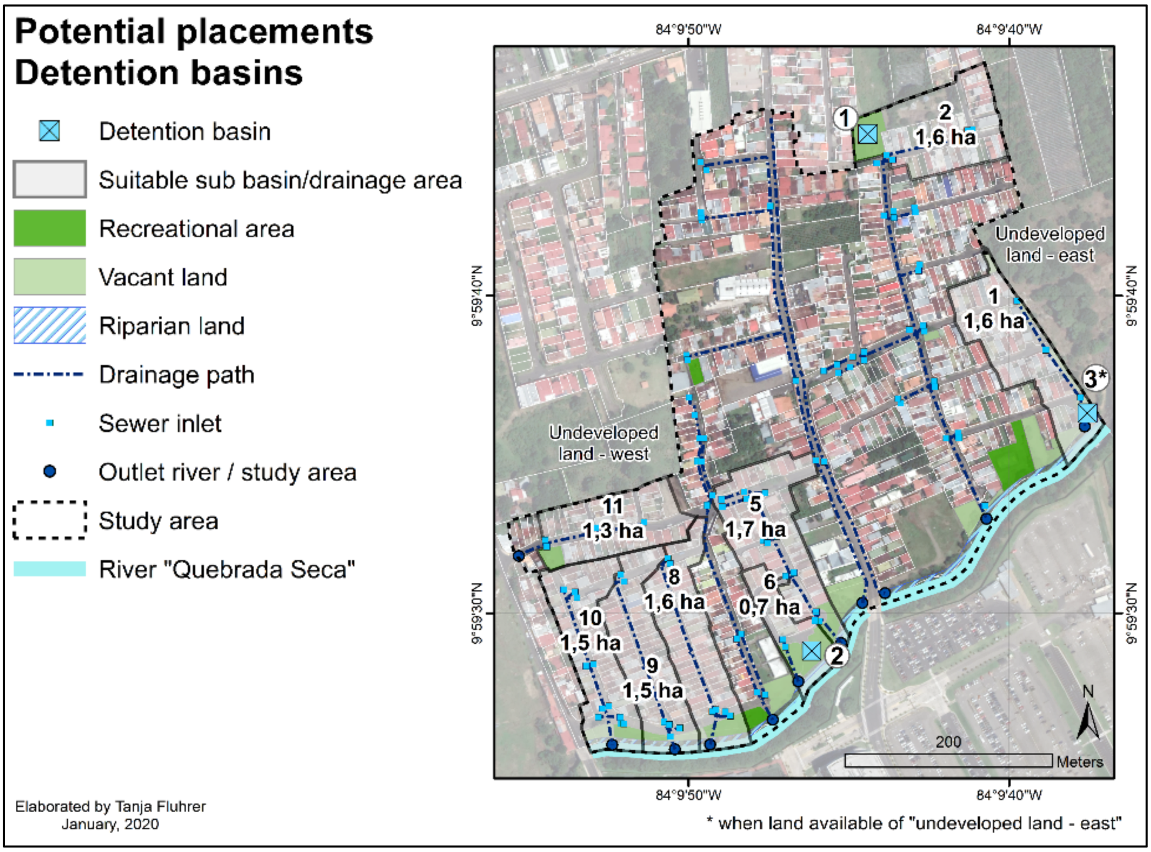

Fig. S6: Potential placements for detention basins identified in the representative neighbourhood (Fluhrer and Hack 2020). Source of background image: Google Earth.

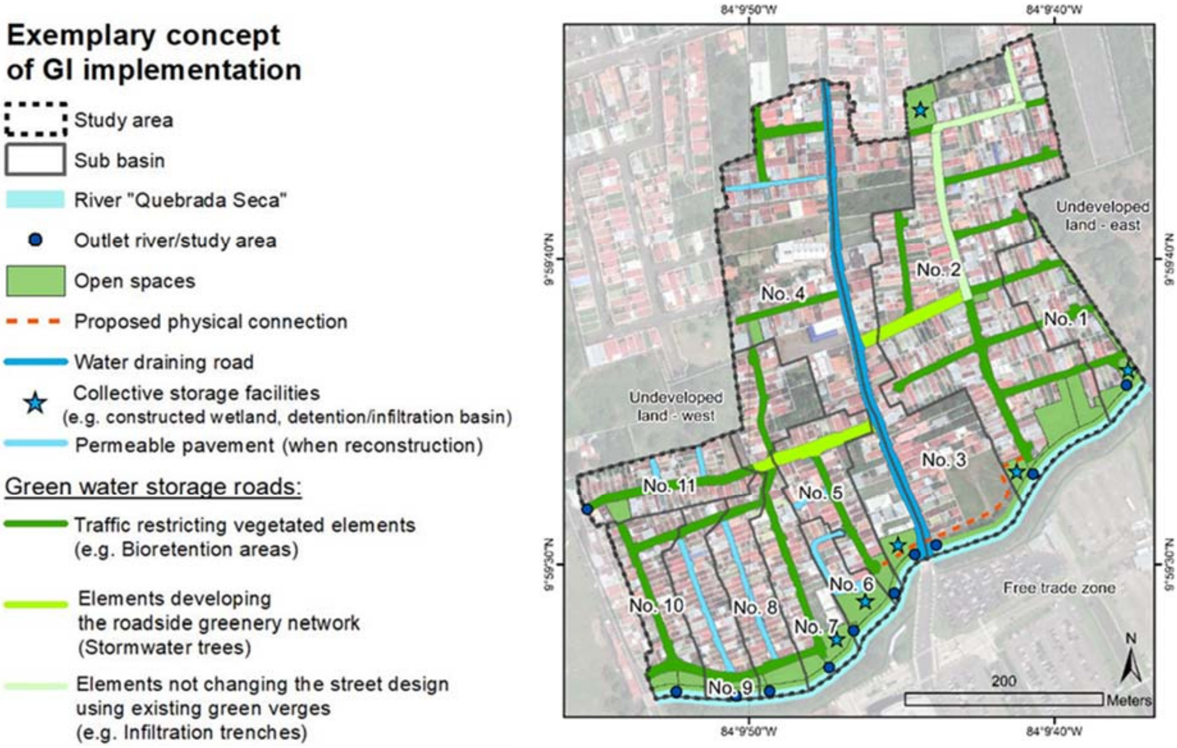

Fig. S7: Maximum realistic potential for Urban Green Infrastructure implementation in public space within the representative neighbourhood (Fluhrer and Hack 2020).

AppendixS2. Characteristics and model parametrization for each subcatchment

Table S1: Area and land cover characteristics of the representative area and the sub-catchments employed in PCSWMM to model the Quebrada Seca catchment. Sub-catchments highlighted in grey are considered as critical due to their high degree of impervious area and relative share of contribution to flooding

Sub-catchment	Total Area [ha]	Area bare soil	Area high vegetation	Area low vegetation	Impervious Area
A9	235.6	27%	9%	14%	49%
A8	228.2	31%	23%	27%	18%
A7-2	30.0	37%	12%	28%	23%
A7-1	68.4	28%	16%	14%	42%
A7	139.6	33%	18%	20%	29%
A6-1	233.3	29%	4%	10%	58%
A6	173.7	25%	5%	15%	55%
A5-1	197.1	27%	8%	13%	52%
A5	28.3	29%	7%	18%	46%

A4-1	67.7	22%	17%	19%	42%
A4	195.5	22%	9%	11%	58%
A3	117.1	27%	9%	15%	48%
A2	73.7	32%	18%	22%	28%
A11	100.7	26%	7%	13%	55%
A10	126.2	28%	14%	21%	37%
A1	231.8	26%	29%	34%	10%
A0	38.5	25%	30%	33%	12%
Representative area	33.0	20%	7%	14%	59 %

Table S2: Overview of the model input data with data type, resolution, date of origin / period of time, source and processing of the used data

Data type	Resolution	Source	Date / Period	Processing
Land use	0.5 m Pixel resolution	Satellite image from Google Earth Pro	January 2019	Land use classification in QGIS with “Semi-Automatic Classification Plugin”
Soil data	n.a.	Ministry of Agriculture and Livestock	1991	n.a.
Potential evaporation	Monthly mean values	UN data; Station Juan Santamaría	Values based on the period 1971 – 1990	Conversion to actual evaporation with the factor 0.7
Precipitation	5 min	Municipality of Belén, and University of Costa Rica – CIEDES	Since July 2017	n.a.
Runoff	5 min	Hydrostatic pressure sensor (TD-Diver™ and Baro-Diver®) in Flores	Since June 2019	Hydrostatic pressure equation and Gauckler-Manning Formula to calculate runoff

Table S3: Model parametrization for each sub-catchment. Parameterization of Drying Time and Curve Number based on (USDA 1986; Oreamuno Vega and Villalobos Herrera 2015; Rossman and Huber 2016)

Name	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Impervious (%)	Drying Time (days)	Curve Number	Soil type
A0	38.5	573.0	671.9	10.5	12.3	5.0	24.7	Zarcero, Concepción
A1	232.0	1163.2	1994.3	12.7	10.5	8.4	30.5	Zarcero, Concepción
A10	126.3	945.5	1335.6	6.3	37.0	4.3	34.9	Heredia
A11	100.8	819.4	1229.9	7.9	54.7	4.3	36.8	Heredia

A2	73.7	546.3	1349.5	12.8	28.2	9.1	34.9	Concepción, Heredia
A3	117.2	1069.6	1096.0	9.2	48.2	5.0	36.1	Concepción, Heredia
A4	195.7	1390.5	1407.4	7.4	57.8	4.3	35.9	Heredia
A4-1	67.7	576.8	1174.0	8.1	42.4	4.3	33.8	Heredia
A5	28.3	441.2	641.0	6.0	45.5	4.3	36.3	Heredia
A5-1	197.2	1400.0	1408.8	5.7	52.3	4.3	36.6	Heredia
A6	173.9	1331.3	1305.9	6.5	55.3	4.0	36.6	Alajuela
A6-1	233.5	2187.0	1067.5	5.9	57.8	3.7	38.3	Alajuela
A7	139.7	1260.6	1108.4	7.3	28.7	4.3	35.2	Alajuela
A7-1	68.4	458.4	1493.0	6.2	42.2	4.3	35.3	Alajuela
A7-2	30.0	410.7	731.0	6.2	23.2	4.3	35.4	Alajuela
A8	228.4	848.0	2692.9	11.2	18.1	10.9	33.9	Zarcero, Concepción
A9	235.8	1176.6	2004.2	7.3	49.1	4.5	36.1	Concepción, Heredia

Table S4: Soil type parametrization (Oreamuno Vega and Villalobos Herrera 2015)

Name	**Zarcero**	**Alajuela**	**Concepción**	**Heredia**
Soil type	I 099	I 108	I 110	I 111
Texture	loam (medium)	loam/clay-loam	clay, fine	loam/clay-loam
Slope	12-25%	10-20%	10-20%	12-25%
Matrix material	Volcanic ashes	Ignimbrites with volcanic ashes mantles	Volcanic ashes and lava	Volcanic ashes over lava and lahars
Drainage	Good	Moderate - Good	Good	Good
Water level (cm)	+120	Deep	Deep	+120
Average annual precipitation (mm)	2550-5680	1900-2400	2300-2800	1900
Average annual temperature (°C)	15-18	21-26	18-24	21-24
Pedological horizons				
Ap	Sandy loam	Loam	Clay	Clay
A2	Loam	Loam		
AB	ND	Clay loam		
Bw1	Sandy loam	Clay loam		
Bw2	ND	Clay loam		
BC	Loam	Clay silt		
Max depth (cm)	150	113+	85	145
Hydrologic soil group	A	B	B	B

Appendix S3. Calibration and validation

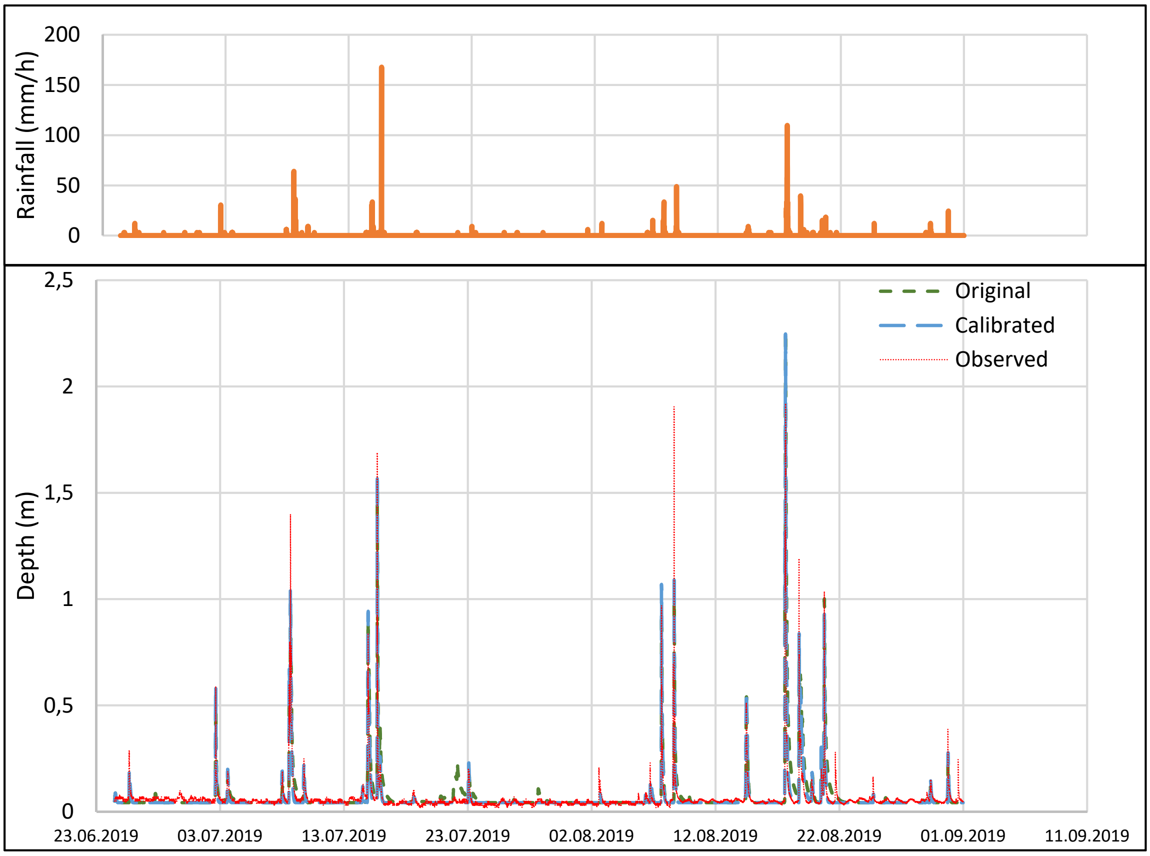

Fig. S8: Control point depth data and rainfall distribution after sensitivity analysis and calibration

Table S5: Error coefficients for calibrated model

Error	Original	Calibrated
Integral square error rating	Excellent	Excellent
Integral square error (ISE)	0.607	0.424
Nash-Sutcliffe efficiency (NSE)	0.503	0.758
Coefficient of determination (R2)	0.636	0.774
Standard error of estimate (SEE)	0.08	0.0559

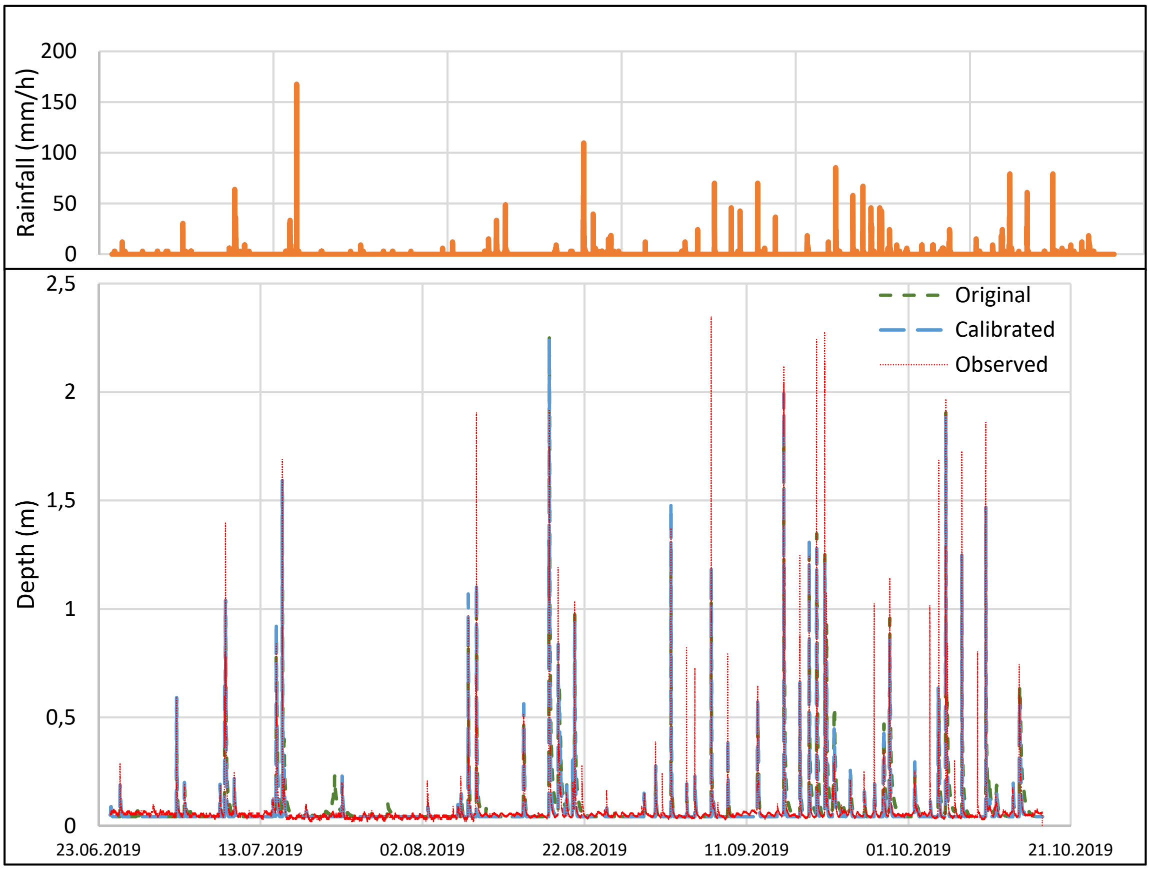

Fig. S9: Control point depth data and rainfall distribution for complete period